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ESW

SHOCK-RESISTANT ENCLOSURE

Related Application

Provisional Application No. 60/400,940, filed August 1, 2002, the priority of which is claimed.

Background of the Invention

Field of Invention

This invention pertains generally to enclosures for devices with fragile components and, more particularly, to a shock-resistant enclosure which is particularly suitable for use with solid state angular rate sensors and the like.

Related Art

Angular rate sensors commonly have sensing elements in the form of small quartz tuning forks which are relatively fragile and require protection from impact prior to, during and after installation. Heretofore, such protection has been provided by mounting the sensing element on a support structure such as a printed circuit board and then suspending the support structure within a housing with an elastomer or other flexible material. The flexible suspension absorbs a portion of applied shocks and limits the energy transmitted to the sensing element.

While providing some measure of shock protection, the flexible material can also degrade the performance of the sensor. This happens because the flexible material permits movement of the sensing element within the enclosure in response to shock or vibration of the unit. If sensing element

rotates within the housing, it will produce an erroneous output signal which cannot be distinguished from the signals produced by rotation of the unit and the structure on which it is mounted.

Objects and Summary of the Invention

It is, in general, an object of the invention to provide a new and improved shock-resistant enclosure.

Another object of the invention is to provide a shock resistant enclosure of the above character which is particularly suitable for use in angular rate sensors.

These and other objects are achieved in accordance with the invention by providing a shock-resistant enclosure which has a housing to which a fragile element is rigidly mounted, and a plurality of discrete shock absorbing elements projecting from the housing in different directions for receiving impacts which would otherwise strike the housing. In some embodiments, the shock absorbing elements include elastomeric bumpers which are formed integrally with a gasket that provides a seal between two sections of the housing. In others, they include plastic fenders or springs which are formed integrally with and of the same material as the housing.

Brief Description of the Drawings

Figure 1 is an isometric view of one embodiment of a shock-resistant enclosure in accordance with the invention.

Figure 2 is an isometric view of a combined gasket and bumper structure utilized in the embodiment of Figure 1.

Figure 3 is an enlarged, fragmentary, isometric view illustrating the manner in which forces impact upon the shock absorbing elements in the embodiment of Figure 1.

Figures 4 - 6 are graphical representations illustrating the manner in which shock impulses are mitigated by the invention.

Figures 7 and 8 are isometric views of additional embodiments of a shock-resistant enclosure in accordance with the invention.

Detailed Description

As illustrated in Figure 1, the shock-resistant enclosure includes a housing 11 in which a device such as an angular rate sensor having a fragile element such as a quartz tuning fork is enclosed. The fragile element is affixed rigidly to the housing, with no shock absorbing element between the fragile element and the housing. It could, for example, be mounted on a circuit board affixed to the housing, or it could be affixed with an adhesive. As used herein, the term "rigidly" does not require absolute rigidity, but rather encompasses any type of mount that does not include a shock absorber.

The housing is formed in two sections — a base 12 and a cover 13 which, in the embodiment illustrated, are held together by screws 14. It will be understood, however, that the two sections can be held together by any suitable means, including rivets, snaps or with an adhesive.

An elastomeric gasket and bumper structure 16 provides both a seal between the two sections and protection from impact or shock. As best seen in Figure 2, structure 16 includes a generally rectangular sealing ring 17 which is received between the two sections of the housing, and a plurality of discrete bumpers 18, 19, 21, 22 which project from the housing in different directions and serve as shock absorbing elements.

Bumpers 18, 19 lie generally in the plane of the sealing ring and project laterally from sides and ends of the housing. Bumpers 21 also lie generally in the plane of the seal and extend diagonally from the corners of the housing. They are connected to the base portions of bumpers 18, 19 by

runners or bridges 23. Bumpers 22 project from a face 24 of the housing which is generally parallel to the plane of sealing ring 17. They are joined to bumpers 18, 19 and the sealing ring by runners 26.

The gasket and bumpers are formed as an integral structure of rubber or another suitable elastomer by a process such as injection molding.

The bumpers are positioned near the corners of the housing and, in the embodiment illustrated, are held in place by cornerpieces 27 which are retained by the screws 14 that hold the two sections of the housing together. Runners 23 are thus captured between the bottoms of the cornerpieces and a flange on the housing cover, and runners 26 are embedded in recesses formed in the side walls of the cover next to the cornerpieces. The two bumpers at each corner are joined together by gussets 29 that are received in recesses in the outer face of the cover.

Alternatively, if desired, the bumpers and runners can be over-molded onto the housing to form an integral structure, with the runners being received or embedded in recesses in the outer surfaces of the housing walls and thereby integrally attached to the housing. In that case, the cornerpieces are not required.

The bumpers are tapered and decrease in cross section away from the housing, *i.e.,* broader at the base and thinner at the tip. This gradient in flexibility has been found to provide better shock absorption characteristics than bumpers having a uniform cross section throughout their length.

Mounting pads 31 extend laterally from the base of the housing, and additional impact resistance is provided by shock absorbing fenders 32 which surround the outer edge portions of the pads. In the embodiment illustrated, the fenders are in the form of C-shaped springs which are generally coplanar with and spaced laterally from the mounting pads. Fenders 32 include lugs

33 which project beyond the lower surfaces of the mounting pads. The fenders and lugs are formed integrally with and of the same material the base section of the housing, and in the presently preferred embodiments, they are formed of a plastic material.

The bumpers and fenders protect the housing and its contents from impacts such as being dropped onto the floor or other hard surface either prior to or during installation, as well as impacts or shock occurring thereafter. With the bumpers and fenders extending in different directions, an impact coming from any direction can be absorbed by one or more of them, rather than striking the housing directly.

Thus, bumpers 18, 19, 21 will absorb impacts in the plane of the sealing ring, *i.e.,* those directed toward the sides and/or ends of the housing, and bumpers 22 will absorb impacts directed toward the face of the cover. Fenders 32 absorb impacts both in and perpendicular to the plane of the mounting pads.

The shock energy transmitted to the tuning fork or other fragile element within the housing is a result of the acceleration that occurs when the device receives an impact. Acceleration is the change in velocity over time, or dv/dt, and for a given change in velocity, the amount of acceleration can be decreased by extending the time over which it occurs.

Figure 4 shows the effect of a body impacting upon a hard, immovable surface. That causes an abrupt change in velocity in a very short time and, thus, a very large shock. This impulse is sometimes referred to as a "saw-tooth" shock pulse.

The invention reduces the shock by extending the time of acceleration. In the example of Figure 5, the elastomeric bumpers and plastic fenders absorb the shock pulse to the point of zero velocity. While this total absorption is the optimal condition, it is usually not necessary to provide this much mitigation.

Figure 6 illustrates a practical example in which the majority of the energy is absorbed. Here, the velocity decreases gradually until the shock absorbers bottom out or otherwise reach the limit of their capacity, following which the remaining energy is dissipated in a very short period of time. Since the velocity is reduced substantially before the limit is reached, acceleration and shock are reduced significantly.

The embodiment of Figure 7 is similar to that of Figure 1 except for the bumpers. In this embodiment, bumpers 18, 21 once again extend in the plane of the seal, but bumpers 22 have been replaced with rounded bumpers 36 which project beyond the outer face of cover 13. In addition, the upper side of the housing is protected by leaf springs 37. Those springs are formed integrally with and of the same material as base 12, and they are cantilevered from it.

In the embodiment of Figure 8, shock absorbing fenders 39 are provided at the corners of the housing 41. These fenders extend around the corners and are spaced laterally from them, with lugs 42 projecting beyond the surfaces 43, 44 of the housing which are bounded by the corners. They absorb impacts in the planes of the fenders as well as those which are perpendicular or oblique to those planes. Fenders 39 and lugs 42 are formed integrally with and of the same material (*e.g.* plastic) as the housing.

The invention has a number of important features and advantages. It provides effective protection against impact and shock for fragile elements within a housing while permitting those elements to be mounted rigidly to the housing.

In applications where the enclosure is for a rate sensor or other device in which the fragile element is mounted on a circuit board and connections with the circuit board are made through the housing via pins, the need for flexible

connections between the circuit board and the pins is eliminated. With the circuit board affixed rigidly to the housing, the connections can also be rigid.

With the individual bumpers, the elastomeric material is employed only in discrete locations and is configured to provide more desirable shock absorbing characteristics.

In some embodiments, the elastomeric bumpers are formed as part of an integral structure which also includes a sealing gasket for the housing, and both the bumpers and the gasket are formed in a single manufacturing step. Being connected, they can be molded simultaneously, which provides a significant advantage both in manufacturing and in handling.

Additional shock absorbing elements are molded into the housing itself and designed to absorb impact along more than one axis without interfering with the mounting of the device in its ultimate application, *e.g.* a yaw rate sensor bolted into an automobile or other vehicle.

The bumpers and gasket are provided economically by forming them of the same material and in a single manufacturing process. Further cost saving results from having individual bumpers in discrete locations, rather than a single coating of elastomeric material over the entire housing, and the tapered shape of the shock absorbers provides a substantially smaller peak rate of acceleration than a constant cross section. If desired, the rubber bumpers and gasket can be molded onto the housing or attached by other suitable means.

The fenders are also produced economically by forming them integrally with the housing without the use of a separate material or an over-molding step. Their shape and positions allow them to absorb shock from a number of different angles, and they are designed to deflect during installation so as not to interfere with the mounting of the housing.

It is apparent from the foregoing that a new and improved shock-resistant enclosure has been provided. While only certain presently preferred embodiments have been described in detail, as will be apparent to those familiar with the art, certain changes and modifications can be made without departing from the scope of the invention as defined by the following claims.